# FERMI
## Gamma-ray Space Telescope

## Lunar gamma ray emission seen during the first year by Fermi

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# Sources in Solar System

- Sources:
  - The Moon
  - The Sun (quiet and/or flaring)
  - The Earth
- Potential Sources

Asteroids in different populations:
  - Main Asteroid Belt (MBAs)
  - Jovian and Neptunian Trojans (Trojans)
  - Kuiper Belt Objects (KBOs)
- Other planets

  - Debris (< few meter size, dust, grains) MBAs, Trojans, KBOs Oort Cloud

# Solar system objects observation interest

- Moon gamma ray emission depends on the flux of CR nuclei near its surface

- Quiet solar gamma ray emission has two components: IC due to the CR electron scattering off solar photons in the heliosphere and the CR nuclei interactions with the solar atmosphere

- Therefore the gamma ray emission studies are a sensible probe for CR fluxes in the solar system

- Gamma ray flux measurements during the entire solar cycle will be very important!

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# Emission mechanism

- "γ-ray albedo" due to CR interactions with surface material:

- **Moon rock (solid)**

- **Solar atmosphere (gaseous)**

Lunar γ-ray emission:

- γ-rays produced by $\pi_0$ decays produced in hadronic showers

- we expect lunar limb brighter then central disk

- γ-ray  spectrum should be soft

Similar emission mechanism for any solid object in solar system

CR

γ
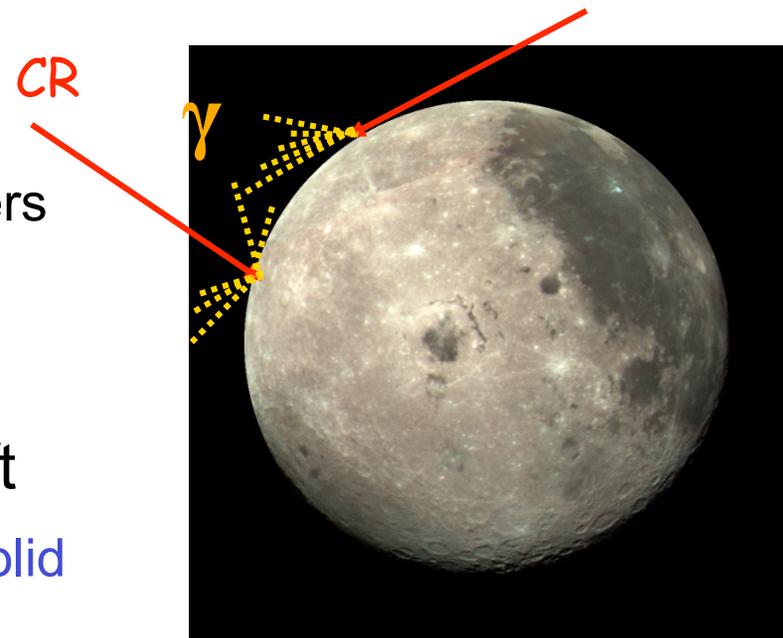
# Data selection

- Data from Aug 2, 2008 until March 1, 2009

- Analysis in celestial relative coordinates (Moon and Sun centered data)
  - SUN is moving about 1°/day
  - MOON is moving about 15°/day
- E > 100MeV
- Zenith angle < 105° (to avoid the Earth limb)
- Galactic Plane Cut (>30°)
- Moon-Sun angular separation >20°
- **ROI: 10°**
- **True/Fake source comparison**

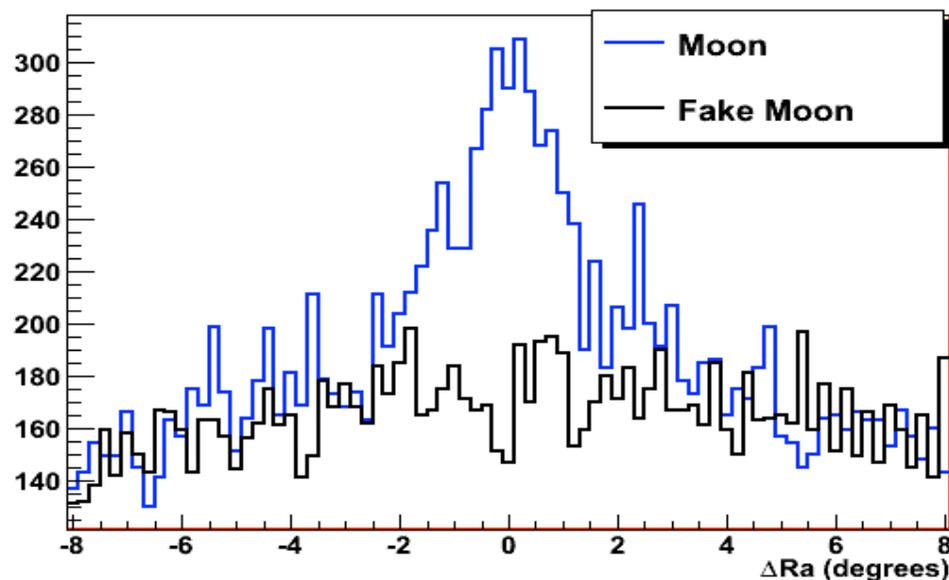# Background estimation approach

### The "fake" source method:

A fake source follow the path of the real source (on the ecliptic) but 30 degrees away (passes through the same areas on the sky but at different times)



**fake moon
(30° from true moon)**

True moon
position
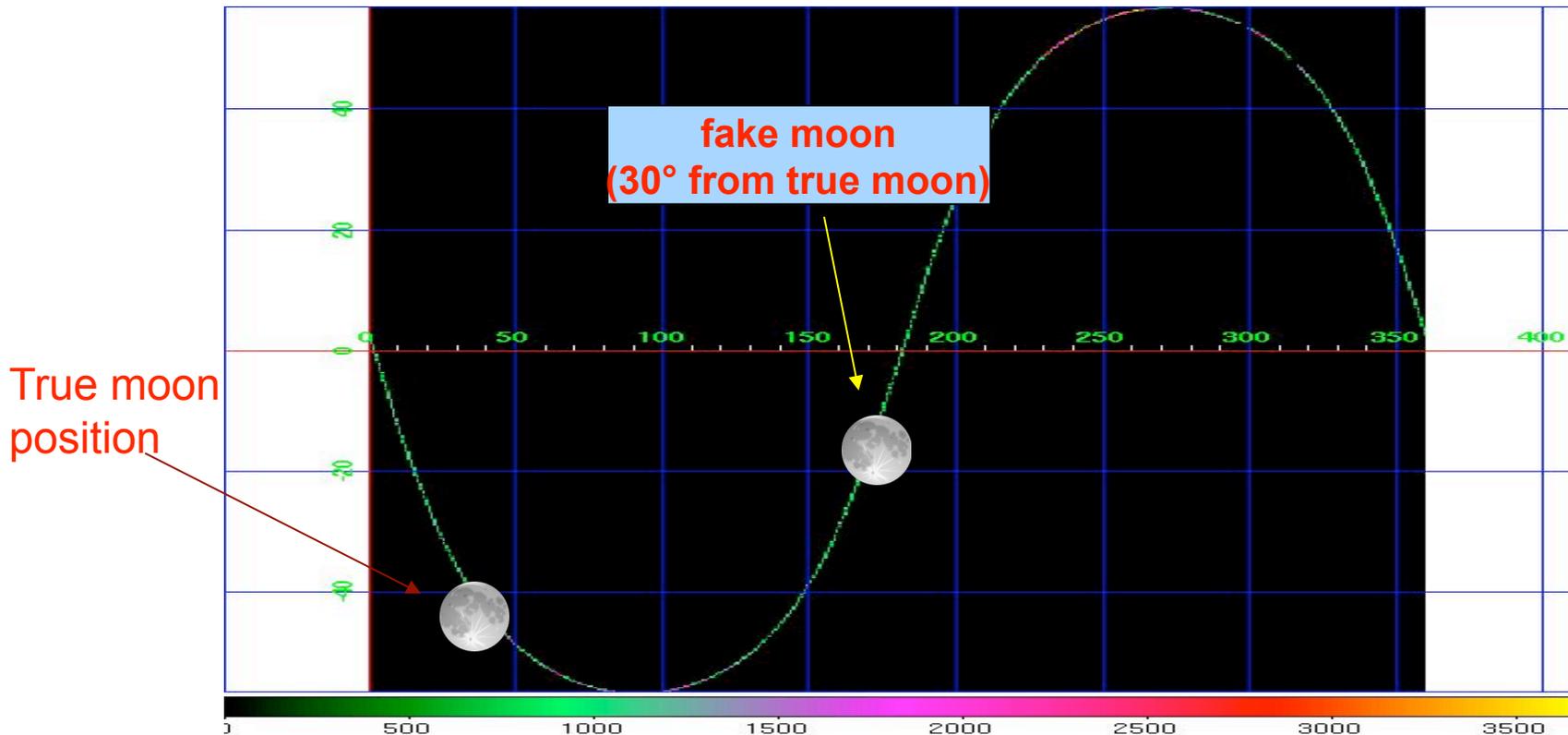
**Example of monthly lunar path (along the ecliptic) in galactic coordinates**
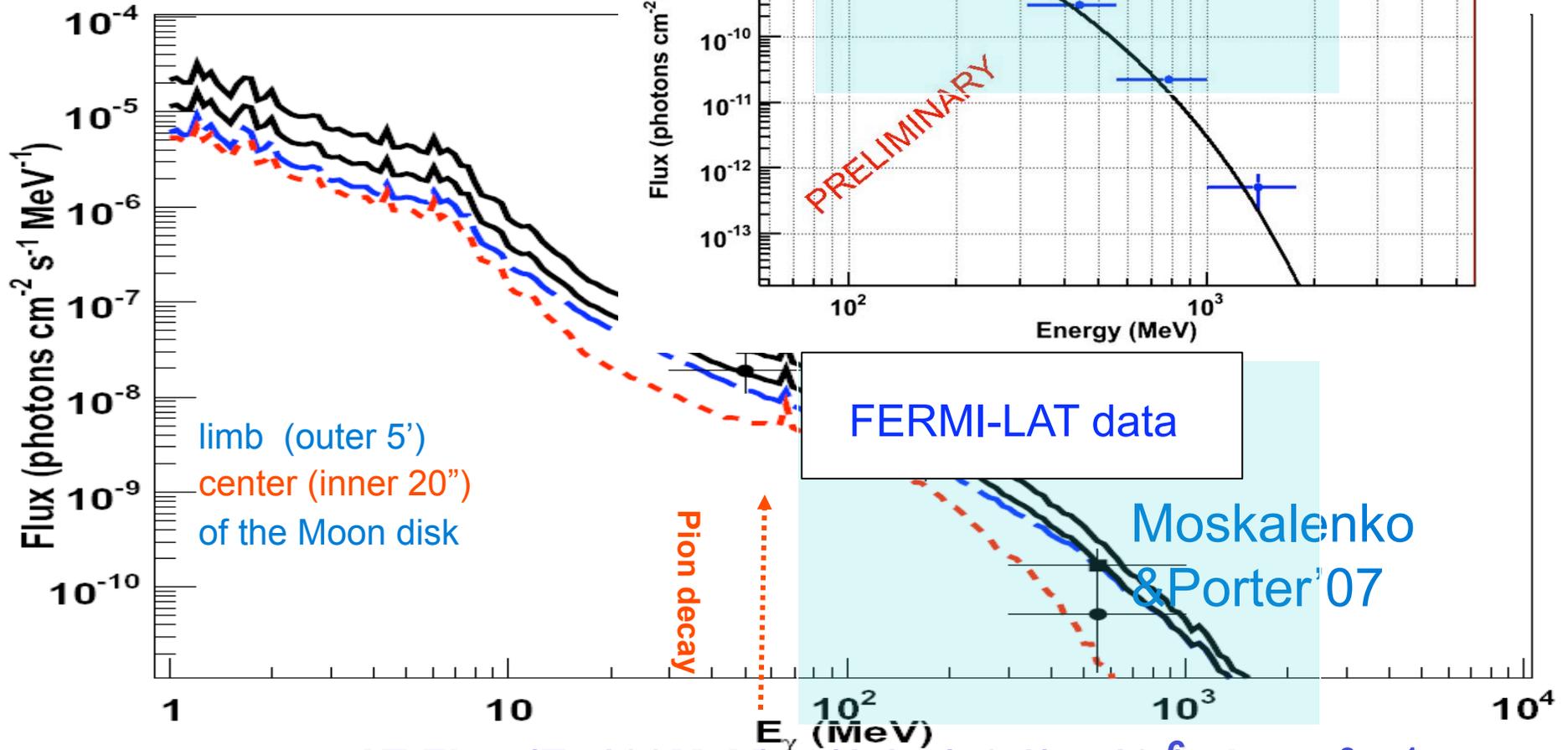
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**Relative RA for MOON E>100MeV**



Moon count map and projections in RA and DEC axes centered on Moon position.

E>100MeV
0.2deg/bin
gaussian smothed





*PRELIMINARY*

**Relative DEC for MOON E>100MeV**

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# Moon Spectra



limb (outer 5')
center (inner 20")
of the Moon disk

Pion decay

FERMI-LAT data

Moskalenko
&Porter'07

PRELIMINARY

Fermi data

Exponential cutoff power law fit
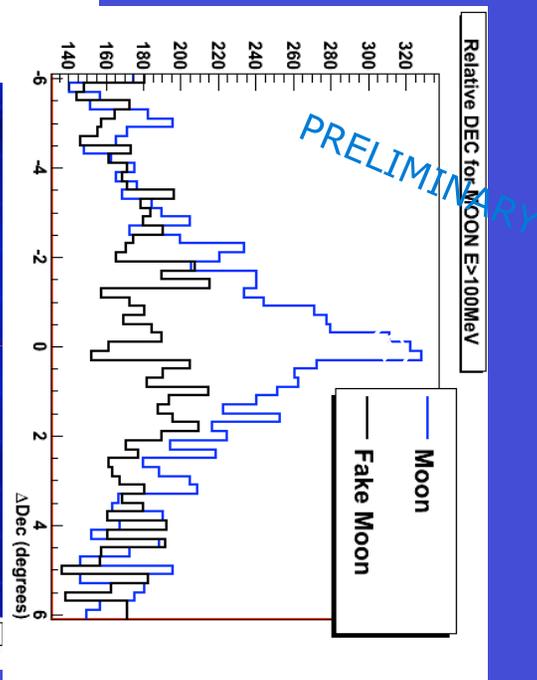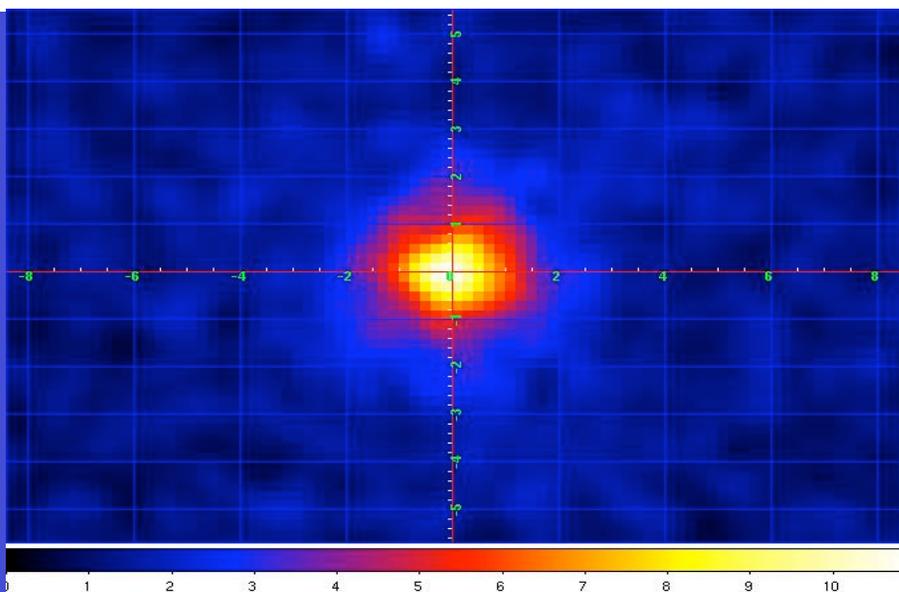
LAT Flux (E>100MeV) = (1.1 +/- 0.2) x $10^{-6}$ ph cm$^{-2}$ s$^{-1}$
(statistical + 20% systematic error)
EGRET Flux(E>100MeV) =(5.55+/-0.65)x $10^{-7}$ ph cm$^{-2}$ s$^{-1}$

# Sun and Moon spectra: a comparison



Unfolded $E^2$ flux (MeV phot/(cm$^2$ sec)

PRELIMINARY
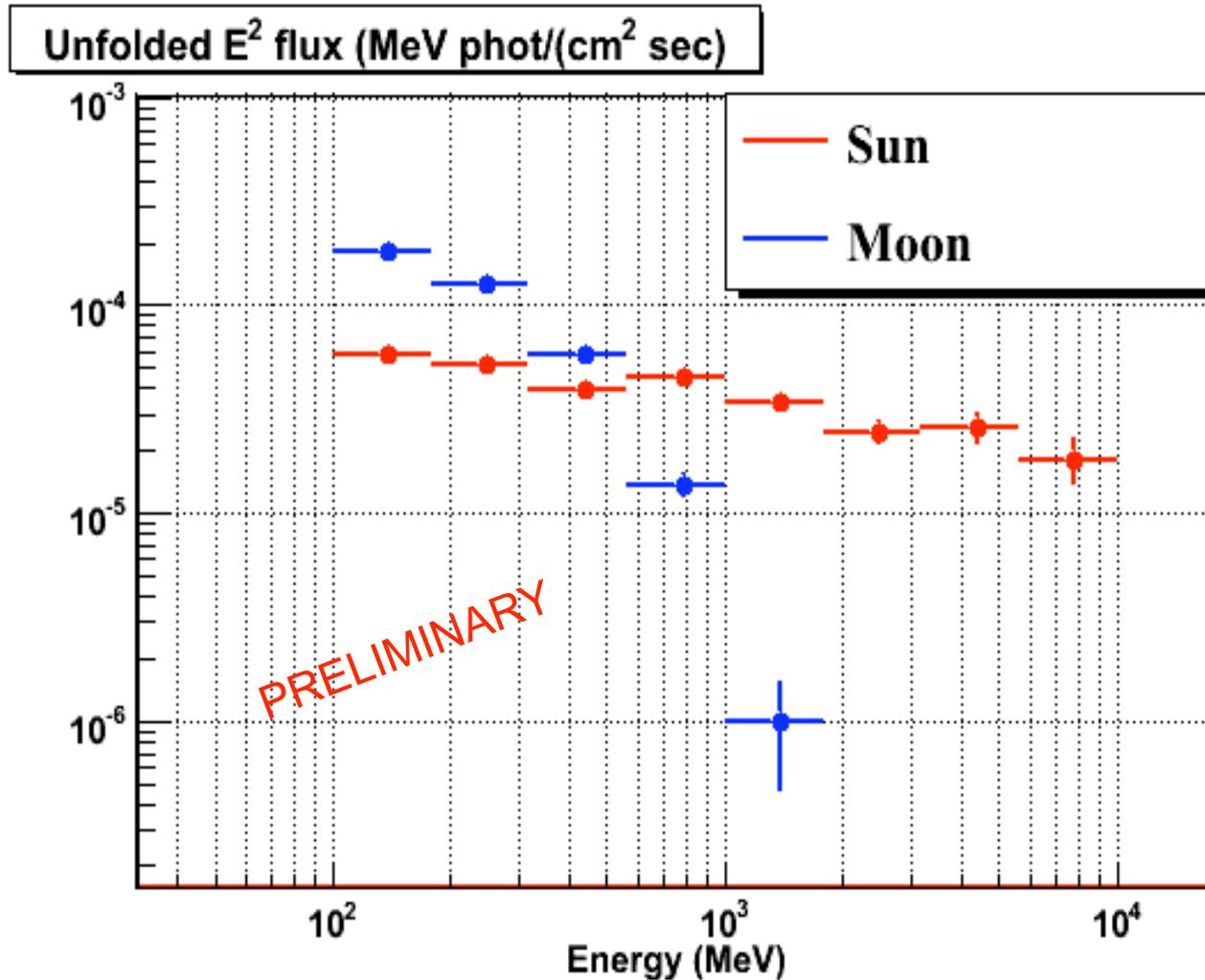
**Moon and Sun Spectra Compared**

# CR Fluxes comparison
## (from EGRET era to now)
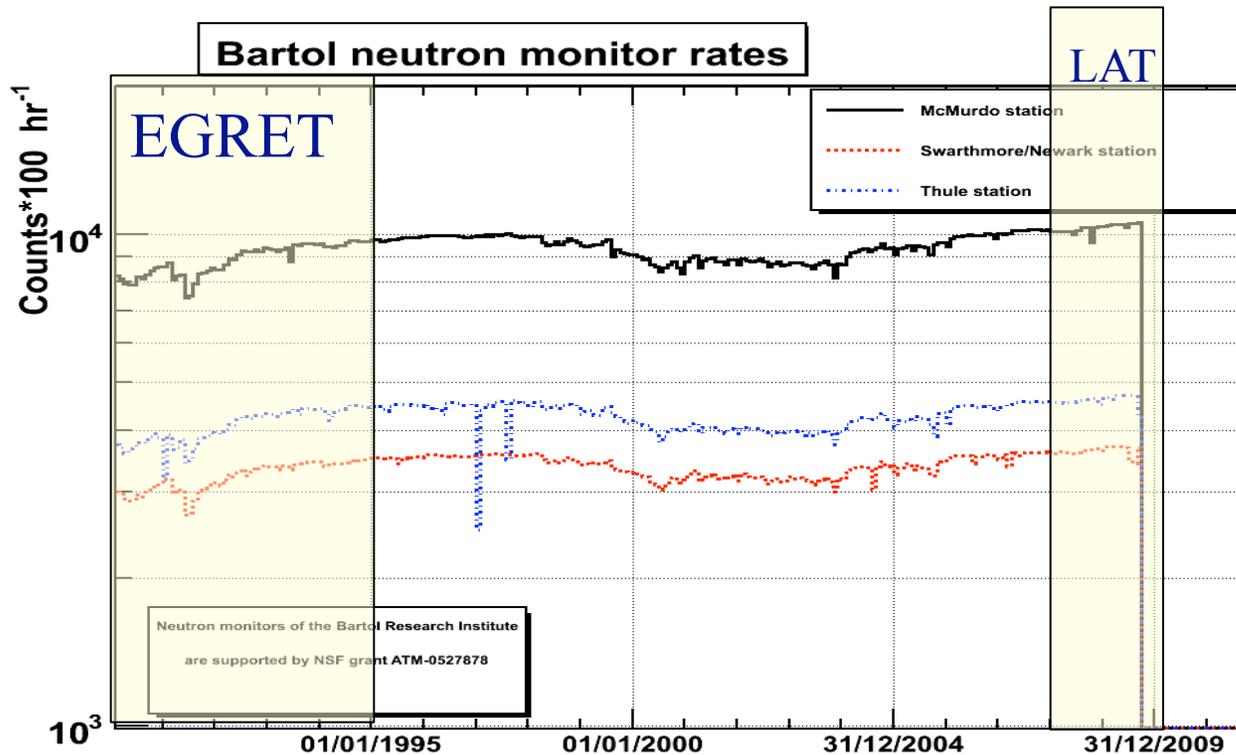


Actual CR fluxes are ~10% higher than EGRET era

**Search for emission from other objects in the solar system:**

- **Jupiter trojans and asteroids are potentially emitting gamma-rays**
- **Many of these objects lie along the ecliptic plane**
- **Any pointlike or extended emission along the ecliptic plane is carefully checked**
- **No evidence of emission till now**
- **The galatic plane emission clearly visible on side**



Most of jupiter trojans are along this line

PRELIMINARY

0.000
-30.000
60.000    30.000    0.000    330.000    300.000

0    2    4    6    8    10    12    14    16    18    20
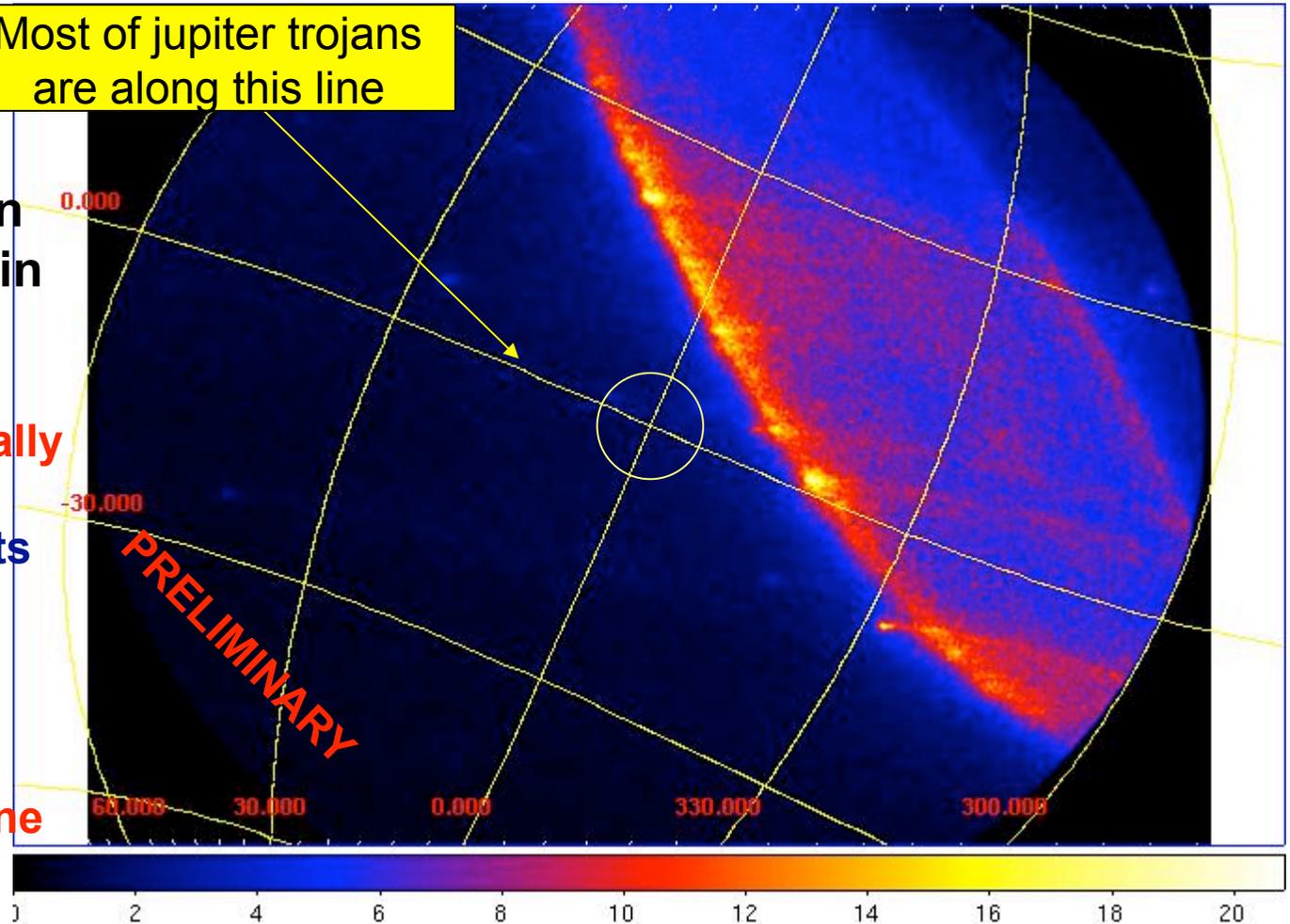
**Photon count map during the first 10 months centered on Jupiter position (marked by a circle).** The colored vertical scale is linear and a smoothing has been applied to the image. The bin width used is 0.2°. The coordinates are celestial coordinate offsets respect to Jupiter position, the axes drawn represent the ecliptic coordinates.

# Conclusions

➢ During the first months of data taking Fermi has observed the quiet Sun and the Moon emission

Preliminary Spectra and Fluxes has been reported for both sources

The Fermi preliminary results are consistent with predictions at solar minimum activity

Search for gamma-ray emission from any other solar system object in progress